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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE				
PETITION TO REVIVE UNDER 37 C.F.R. 1.137(b) (Unintentionally Abandoned)		Docket Number: 12928/10019		
Application Number 10/506,360	International Filing Date 19 February 2003	Examiner Not Yet Known	Art Unit Not Yet Known	Conf. No. Not Yet Known
Invention Title METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT		Inventor(s) CALLENS et al.		

Address to:
Mail Stop PCT
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

Attention: Office of Petitions

Sir:

The above-identified application became abandoned for failure to timely enter the national phase. The abandonment date of this application is September 2, 2004.

This application was untimely filed on September 2, 2004 and accorded Serial No. 10/506,360, due to a local postal disturbance in New York City wherein the "date in" date for express mail was provided the next day filing date due to the Republican National Convention. The 30 month national phase filing date was September 1, 2004. Therefore, we are petitioning to have this application revived.

1. The Petition fee of $1,330.00 and any additional fees are authorized to be charged to our Deposit Account No. 11-0600. This Petition is being filed in duplicate.

2. This petition is accompanied by the original request (mailed September 2, 2004) to enter the national stage in the United States under 35 U.S.C. 371.

The following originally filed items are enclosed:

a. Transmittal Letter to the U.S. Designated/Elected Office (Form PTO 1390) requesting

entry in the U.S. national stage and the appropriate fee;

b. English translation of International Application with drawings;

c. Preliminary Amendment;

d. Substitute Specification and Marked/Up Copy thereof;

e. Unsigned Declaration & Power of Attorney

f. International Search Report; and

g. Information Disclosure Statement and PTO-1449.

The delay in entering the national phase was unintentional.

Respectfully submitted,

Date: Nov 12, 2004

Jon M. Vorel 48912
Richard L. Mayer
Reg. No. 22,490

KENYON & KENYON
One Broadway
New York, New York 10004
212 425-7200
Customer No. 26646

BT14 Rec'd PCT/PTO 12 NOV 2004

FORM PTO-1390 (REV. 10-2003) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

AT[redacted]'S DOCKET NUMBER
12[redacted]019

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

INTERNATIONAL APPLICATION NO	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED:
PCT/FR03/00556	19 February 2003 (19.2.2003)	1 March 2002 (1.3.2002)

TITLE OF INVENTION
METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT

APPLICANT(S) FOR DO/EO/US
Catherine CALLENS, Helene SEGURA

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4) (unsigned)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A preliminary amendment.
14. ☐ An Application Data Sheet under 37 CFR 1.76.
15. ☒ A substitute specification and a marked-up version thereof.
16. ☒ A power of attorney and/or change of address letter (in unsigned Declaration).
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.2 and 37 CFR 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information: International Search Report with translation.

EXPRESS MAIL NO. EV 321 890 084US

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO. PCT/FR03/00556	ATTORNEY'S DOCKET NUMBER 12[illegible]0019

21. ☒ The following fees are submitt[illegible]

BASIC NATIONAL FEE (37 CFR 1.[illegible])(1)-(5)):

	CA[illegible]LATIONS PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1080.00**	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$920.00**	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$770.00**	
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$730.00**	
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**	

ENTER APPROPRIATE BASIC FEE AMOUNT =				$920.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	8 - 20 =	0	X **$18.00**	$	
Independent Claims	3 - 3 =	0	X **$86.00**	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$290.00**	$	
TOTAL OF ABOVE CALCULATIONS =				$	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$	
SUBTOTAL =				$920.00	
Processing fee of **$130.00** for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$920.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$920.00	
				Amount to be refunded:	$
				charged	$

a. ☐ A check in the amount of $__________________ to cover the above fees is enclosed.

b. ☒ Please charge my **Deposit Account No. 11-0600** in the amount of **$920.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to **Deposit Account No. 11-0600**. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:
KENYON & KENYON
One Broadway
New York, New York 10004
CUSTOMER NO. 26646

John M. Vereb
SIGNATURE

John M. Vereb (Reg. No. 48,912)
NAME

September 1, 2004
DATE

NY01 722536 v 1

IN THE U.S. PATENT AND TRADEMARK OFFICE

DECLARATION AND POWER OF ATTORNEY	ATT. DOCKET NO. 12928/10019

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name,

I believe I am an original, first, and sole inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled **METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT**, the specification of which was filed as U.S. Serial No. _____________ on _______________; and was filed as International Application Serial No. PCT/FR03/00556 on 19 February 2003.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me on the same subject matter having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country	(Day/month/year	Priority Claimed	
02 02657	**France**	**1/3/2002**	**Yes X**	**No __**

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys:

Richard L. Mayer (Reg. No. 22,490)
Patrick J. Birde (Reg. No. 29,770)
Jeffrey M. Butler (Reg. No. 41,652)
John M. Vereb (Reg. No. 48,912)

Express Mail No. EV 321891084US

SEND CORRESPONDENCE, AND DIRECT TELEPHONE CALLS TO:

CUSTOMER NO. 26,646

KENYON & KENYON
One Broadway
New York, NY 10004
(212) 425-7200 (phone)
(212) 425-5288 (facsimile)

I declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR	FAMILY NAME **CALLENS**	FIRST GIVEN NAME **CATHERINE**	SECOND GIVEN NAME
RESIDENCE & CITIZENSHIP	CITY **Lyon**	STATE OR FOREIGN COUNTRY **France**	COUNTRY OF CITIZENSHIP **France**
POST OFFICE ADDRESS	POST OFFICE ADDRESS **91 rue Louis Blanc**	CITY **Lyon**	STATE & ZIP CODE/COUNTRY **France 69006**
Signature		Date	

FULL NAME OF INVENTOR	FAMILY NAME **SEGURA**	FIRST GIVEN NAME **Helene**	SECOND GIVEN NAME
RESIDENCE & CITIZENSHIP	CITY **Lyon**	STATE OR FOREIGN COUNTRY **France**	COUNTRY OF CITIZENSHIP **France**
POST OFFICE ADDRESS	POST OFFICE ADDRESS **2 Impasse Belloeuf**	CITY **Lyon**	STATE & ZIP CODE/COUNTRY **France 69003**
Signature		Date	

[12928/10019]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Catherine CALLENS et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

Mail Stop: PCT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

S I R:

Kindly amend the above-captioned application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

On the first page of the claims, first line, please add:
--WHAT IS CLAIMED IS:--.

Please cancel claims 1 to 8 without prejudice.

Please add the following new claims:

9. (New) A method for designing a nuclear fuel assembly which is intended to be positioned in a nuclear reactor, the assembly comprising a plurality of guide tubes and a control cluster which itself comprises a plurality of control rods which are received in the guide tubes and a support for the control rods, the assembly comprising a helical spring for damping an impact of the support against an upper end piece of the assembly in an event of the control cluster falling during a shutdown of the nuclear reactor, comprising:

establishing a progression of speed of the control cluster after the impact of the support against the upper end piece;

establishing, based on the speed of the control cluster after the impact of the support against the upper end piece, a maximum longitudinal load for compression of the spring; and

establishing, based on the maximum longitudinal load for compression of the spring, at least a maximum shearing stress in the spring.

10. (New) The method according claim 9, wherein the maximum shearing stress (τ_{max}) is a shearing stress along a neutral axis of the spring.

11. (New) The method according to claim 9, wherein the maximum shearing stress is a shearing stress along an axis (F2) of the spring nearest a longitudinal center axis (A) thereof.

12. (New) The method according to claim 10, wherein the maximum shearing stress is a shearing stress along an axis (F2) of the spring nearest a longitudinal center axis (A) thereof.

13. (New) The method according to claim 9, further comprising:

verifying, using the maximum shearing stress in the spring, that a maximum stress admissible by the spring has not been exceeded.

14. (New) A system for designing a nuclear fuel assembly, comprising:

a first arrangement configured to establish a progression of speed of a control cluster after an impact of a support against an upper end piece;

a second arrangement configured to establish, based on the speed of the control cluster, a maximum longitudinal load for compression of a spring; and

a third arrangement configured to establish, based on the maximum longitudinal load for compression, at least a maximum shearing stress in the spring.

15. (New) The system according to claim 14, further comprising:

a computer; and

a storage arrangement configured to store at least a program comprising instructions for performing steps of designing a nuclear fuel assembly.

16. (New) An article of manufacture comprising:

an arrangement configured to establish a progression of speed of the control cluster after the impact of the support against the upper end piece, establish based on the speed of the control cluster, a maximum longitudinal load for compression of the spring; and establish, based on the maximum longitudinal load for compression, at least a maximum shearing stress in the spring the article of manufacture configured to be read by a computer.

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1 to 8 in the underlying PCT Application No. PCT/FR03/00556 and adds new claims 9 to 16. The new claims, inter alia, conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(iii) and 1.125(b)(2), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/FR03/00556 includes an International Search Report, dated August 22, 2003, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is respectfully submitted that the subject matter of the present application is new, non-obvious and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

KENYON & KENYON

Dated: 9/1/04

By: John M. Vereb

John M. Vereb
Reg. No. 48,912

One Broadway
New York, New York 10004
(212) 425-7200

METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT

FIELD OF INVENTION [Method for designing the spider spring of a control cluster of a nuclear fuel assembly, a corresponding system, computer programme and product]

The present invention relates to a method for designing a nuclear fuel assembly which is intended to be positioned in a nuclear reactor, the assembly comprising a plurality of guide tubes, and a control cluster which itself comprises a plurality of control rods which are received in the guide tubes and a support for control rods, the assembly comprising a helical spring for damping the impact of the support against an upper end piece of the assembly in the event of the control cluster falling during a shutdown of the nuclear reactor.

BACKGROUND OF THE INVENTION

It will be appreciated that nuclear fuel assemblies must be dependable in order to allow reliable operation of nuclear reactors. [

]Thus, design and construction provisions for such assemblies have been drawn up.

These provisions impose a general framework and minimum criteria which the assembly constructors must take into consideration.

As far as the helical damping spring is concerned, the design provisions require verification by means of tests that the integrity of the spring has not been affected during the impact brought about in the event of a shutdown of the reactor.

Express Mail No EV321 890084US

Although the criterion imposed by the design provisions allows assemblies to be designed with satisfactory reliability, it would be desirable to limit the safety margins during design in order to reduce the mass and the cost of the assemblies constructed.

SUMMARY OF THE INVENTION

An objective [An object] of the invention is to overcome this problem by providing a method which allows reliable nuclear fuel assemblies to be designed, [whilst] while limiting the design margins.

To this end, the invention relates to a method for designing a nuclear fuel assembly which is intended to be positioned in a nuclear reactor, the assembly comprising a plurality of guide tubes and a control cluster which itself comprises a plurality of control rods which are received in the guide tubes and a support for control rods, the assembly comprising a helical spring for damping the impact of the support against an upper end piece of the assembly in the event of the control cluster falling during a shutdown of the nuclear reactor, [characterised in that] wherein the method comprises [,] the following steps:

a) establishing [the] a progression of [the] a speed of the control cluster after the impact of the support against the upper end piece,

b) establishing, based on the speed established in step a), a maximum longitudinal load for compression of the spring, and

c) establishing, based on the maximum longitudinal load for compression, at least a maximum shearing stress in the spring.

According to specific embodiments, the method can comprise one or more of the following features, taken in isolation or according to all technically feasible combinations:

- a maximum shearing stress is a shearing stress along the neutral axis of the spring,

- a maximum shearing stress is a shearing stress along the axis of the spring nearest the longitudinal centre axis thereof,

- the method further comprises a step for verifying, using a maximum shearing stress established in step c), that a maximum stress admissible by the spring has not been exceeded.

The invention further relates to a system for designing a nuclear fuel assembly, [characterised in that] <u>wherein</u> it comprises [means for carrying out] <u>an arrangement for performing</u> the steps of a method as defined above.

According to a variant <u>of the invention</u>, the system comprises a computer and storage [means] <u>arrangement</u>, in which at least a [programme] <u>program</u> comprising instructions for [carrying out] <u>performing</u> steps of the method for designing a nuclear fuel assembly is stored.

The invention further relates to a computer [programme] <u>program</u> comprising instructions for [carrying out] <u>performing</u> the steps of a method as defined above.

The invention also relates to a medium which can be used in a computer and on which a [programme] <u>program</u> as defined above is recorded.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

The invention will be better understood from a reading of the description below which is given purely by way of

example with reference to the appended drawings[, in which:].

Figure 1 is a schematic, perspective [cut-away] cutaway view of a nuclear fuel assembly which is designed by a method according to the present invention[,].

Figure 2 is a schematic, partially sectioned side view drawn to an enlarged scale of the structure of the spider of the assembly of Figure 1[,].

Figure 3 is a partial schematic side view of the assembly of Figure [1] 1, illustrating more particularly a pair comprising a guide tube/control rod[,].

Figure 4 is a block diagram illustrating the system for designing the assembly of Figure 1[,].

Figure 5 is a flow chart illustrating successive steps of the design method carried out by the system of Figure 4[,].

Figure 6 is a progression curve of the falling speed of a control rod before it is introduced in the lower portion of the corresponding guide tube, this progression being calculated by the system of Figure 4[, and].

Figure 7 is a progression curve of the falling speed of the same control rod in the lower portion of the corresponding guide tube, this progression being calculated by the system of Figure 4.

DETAILED DESCRIPTION

Figure 1 illustrates a nuclear fuel assembly 1 which mainly comprises a square-based lattice 2 for nuclear fuel rods 3 and a control cluster 4.

The assembly 1 comprises grids 5 for maintaining the rods 3, [which] the grids 5 [are] distributed over the height of the rods 3. A lower end piece 6 is arranged under the lower ends of the rods 3 and an upper end piece 7 above the upper ends

of the rods 3. The upper end piece 7 is provided with springs 8 for pressing against the upper bearing plate of the reactor core, in which the assembly 1 is intended to be placed.

The control cluster 4 comprises a plurality of control rods 10, for example, 24. Conventionally, the control rods 10 comprise a material which absorbs neutrons.

The rods 3 and 10 extend in parallel with a vertical longitudinal direction L.

The rods 10 are carried at the upper ends thereof by a support 11 which is generally referred to as a spider.

As illustrated more particularly in Figure 2, the spider 11 comprises a vertical central upper head 12 and a series of arms or vanes 13 which extend radially outwards from the lower end of the upper head 12 as far as the radially outer ends 14 thereof. [

]Each control rod 10 is connected to an arm 13 at the upper end thereof.

The upper head 12 of the spider 11 has a central blind hole 15 which opens towards the bottom and in which a damping helical spring 16 is received. The spring 16 extends vertically along a [centre] center axis A. A tightening screw 17 extends substantially over the entire height of the hole 15 and is screwed into the wall 18 delimiting the upper portion of the hole 15.

The lower portion of the screw 17 extends through the base of a retaining ring 20 which rests on the lower end of the spring 16. The head 21 of the screw 17 rests, at the top, against the base of the retaining ring 20 in order to press the spring 16 against the wall 18 of the upper head 12.

MARKED UP VERSION OF THE SUBSTITUTE SPECIFICATION

As illustrated in Figure 3 for a control rod 10, each control rod 10 is received in a respective guide tube 24 which is arranged in the lattice 2 of fuel rods 3. In this manner, 24 pairs comprising a guide tube/control rod are formed. Since each of these pairs has a similar structure, only one will be described below.

The guide tube 24 extends from the lower end piece 6 as far as the upper end piece 7. The guide tube 24 comprises a lower portion 26 of reduced inside diameter and an upper portion 27. The lower portion 26 is connected to the lower end piece 6 by a collared screw 28, through which a vertical through-hole 29 extends.

The lower portion 26 of the guide tube 24 surrounds the control rod 10 with a radial passage gap J.

The upper portion 27 is fixed to the upper end piece 7 and opens at the outside of the assembly [1] 1.

Lateral apertures 30, only one of which can be seen in Figure 4, are provided in the upper portion 27 near the lower portion 26.

When the assembly 1 is placed in a nuclear reactor, the cooling liquid of the reactor fills the interior of the guide tube 24.

Conventionally, the control cluster 4 can be moved vertically relative to the remainder of the assembly 1 in order to allow adjustment of the reactivity during normal operation of the reactor, and therefore variations in power from zero power up to maximum output depending on the vertical introduction of the control rods 10 in the lattice 2 of rods 3. The vertical displacement of the control cluster 24 is conventionally carried out by [way of] a drive rod which is connected to the upper end of the upper head 12.

When the reactor is shut down, the drive rod and the assembly 4 fall [owing] due to gravity.

At the start of this falling movement, the control rods 10 are guided only by the upper portions 27 of the guide tubes 24 and have not yet reached the lower portions 26.

Once the falling action has ended, the lower ends of the control rods 10 are introduced in the lower portions 26. The cooling fluid contained in the portions 26 is then violently forced, on the one hand, upwards thereby and, on the other hand, downwards through the apertures 29 of the collared screws 28.

Each lower portion 26 therefore behaves in the manner of a hydraulic damper braking the falling movement of the corresponding control rod 10, and therefore of the assembly 4.

This braking phase ends at the end of the travel path with the impact of the spider 11 against the upper end piece 7 of the assembly 1.

This impact is carried out by [means of the] a retaining ring 20. During this impact, the spring 16 is compressed vertically in order to absorb the shock.

According to the invention, the assembly 1 has been designed in order to take into consideration the specific stresses brought about in the assembly by the fall of the control cluster 4 during such a shutdown of the reactor.

In this manner, in order to design the assembly 1, in particular a data-processing system 32 has been used, as illustrated schematically in Figure 4.

This system 32 comprises, for example, a computer or data processing unit 34 comprising one or more processors, a storage [means] arrangement 36, input/output [means]

arrangement 38, and optionally display [means] arrangement 40.

Instructions which can be [carried out] performed by the computer 34 are stored in the form of one or more programs in the storage [means] arrangement 36.

These instructions are, for example, instructions in FORTRAN programming code.

These various instructions, when they are [carried out] performed by the computer 34, allow the method illustrated by the flow chart of Figure 5 to be [carried out] performed.

In a first step illustrated by the box 42 of this Figure, the computer 34 calculates, based on data 43, the development of the falling speed of a control rod 10 in the upper portion 27 of the corresponding guide tube 24 in the event of a shutdown of the reactor.

This calculation can be [carried out] performed assuming, for example, that the control rod 10 is first subjected to constant loads:

- gravitational force: fg = Mg,
- Archimedes' thrust: fa = -p gV,
- pressure difference in the core: fc, and

[-]

mechanical friction: fm,

where M and V are the mass and the volume, respectively, of the assembly 4 and the drive rod thereof.

The control rod 10 is also subjected to loads as a function of the speed or position thereof, for example, hydraulic friction which can be obtained from: fh = [-]c1 (M + pV) v^2,

with v = speed of the assembly 4 and therefore of the rod 10 in question.

Thus, the equation of the movement of the rod in the upper portion 27 of the guide tube 24 is as follows:

$$\left(M+\rho V\right)\frac{dv}{dt} = \Sigma f$$

This gives:

$$\frac{dv}{dt} = c2 - c1\ v^2$$

with c1 = hydraulic friction in the guide tube and

$$c2 = \frac{fg + fa + fc + fm}{M + \rho V}.$$

C1 and c2 are, for example, experimental data measured during drop tests of the control cluster 4. These data are, with the other data necessary for the calculation, such as the mass and the volume of the assembly 4 and the drive rod thereof, introduced, for example, in the form of a file 43 by way of the input/output [means] arrangement 38.

The computer 34 resolves the equation of the movement of the control rod 10, for example, using the NEWTON method.

Thus, the progression of the speed of the control rod 10 in the upper portion 27 is known as a function of time. The profile established in this manner can be displayed in the form of a curve by the display [means] arrangement 40. This curve is illustrated by Figure 6.

In this manner, at the end of the step illustrated by the box 42, the speed of the control rod 10 is known at the point of entry to the lower damping portion 26 of the guide tube 24.

Based on the results of the step of box 42, the computer 34 calculates the progression of the speed of the control rod 10 during its fall in the lower damping portion 26.

This step is schematically illustrated by the box 44.

This step can be carried out using the following equation:

$$-\frac{dv}{dt} = c2 - \left(c1 + \frac{SCA\text{x}NCA\Delta P}{M+\rho V \quad v^2}\right)v^2$$

with $$c2 = \frac{fg+fa}{M+\rho V} = \frac{M-\rho V}{M+\rho V}g \text{ [c2 =]}$$

SCA = cross-section of the rod 10 and

NCA [=]number of rods 10 in the assembly 4.

Therefore, the hypothesis that f_c and f_m are negligible is applied here.

The difference ΔP represents the elevated pressure produced in the cooling liquid contained in the guide tube 24, that is to say, the pressure thereof between the lower end of the rod 10 and the pressure present in the upper portion 27 of the guide tube 24.

ΔP can be established by the following formula:

$$\Delta P = \frac{1}{2}pQ^2v^2(EXPA + CONTRA + FECR\text{x}CISA\text{x}z)$$

where $$EXPA = \left(\frac{SCA}{SACM}\left(1\frac{SACM}{SACTG}\right)\right)^2$$

with SM = cross-section of the lower portion 26,

SACM = SM - SCA = cross-section of the annular space between the rod 10 and the lower portion 26,

SACTG = STG - SCA, where STG is the cross-section of the upper portion 27 of the guide tube 24,

$$\Delta P = \frac{1}{2}\rho Q^2 v^2 (EXPA + CONTRA + FECRxCISAxz).$$

The computer 34 [carries out] performs, in the step of box 48, the calculation of a circumferential stress and maximum normal $\sigma_{\theta MAX}$, to which the lower portion 26 of the guide tube 24 is subjected owing to the maximum elevated pressure ΔP_{MAX}. This stress can be calculated based on the formula:

$$\sigma_{\theta MAX} = \frac{1}{2}\Delta P_{MAX}\left(\frac{DPM}{EMP} + 1\right),$$

where DPM = inside diameter of the lower portion 26 and []EMP = minimum thickness of the wall of the lower portion 26.

The system 32 can then provide, owing to the input/output means 38, a first result in the form of a file 49 containing the value $\sigma_{\theta MAX}$ established, and optionally the maximum elevated pressure ΔP_{MAX} established.

Next, the system 32 [carries out] performs the calculation of the progression of the speed of the control rod 10 after it comes into contact with the spider 11 and the upper end piece 7. [

]This calculation step is illustrated by the box 50 in [Figure] figure 5.

This calculation can be [carried out] performed, for example, using the following equation when the ring 20, and therefore the spider 11, is in contact with the upper end piece 7:

$$(M + \rho V)\frac{dv}{dt} = (M - \rho V)g - PRCH - K(z - LAI) - c3\,v$$

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$$CONTRA = 0.4\left(1\frac{SACM}{SM}\right)\left(\frac{SCA}{SACM}\right)^2,$$

FECR = coefficient of loss of load owing to friction in the lower portion 26,

$$CISA = \left(\frac{SCA}{SM}\right)^2 \frac{1}{DM},$$

DM = mean diameter of the guide tube 24 in the upper portion 27,

z = height of the rod 10 introduced in the lower portion 26 of the guide tube 24, and

Q = fraction of liquid, flowing upwards out of the lower portion 26.

The resolution of the equations governing the movement of the rod 10 after entry into the lower portion 26 is carried out by the computer 34, for example, using the RUNGE-KUTTA method.

Thus, at the end of the step 44, the progression of the speed of the control rod 10 in the lower portion 26 of the guide tube 24 is known before the impact of the spider 11 on the upper end piece 7.

The speed profile established in this manner can be displayed, for example, by the [means] arrangement 40, as illustrated in Figure 7. On the curve in Figure 7, the speed profile established during step 44 is the portion located to the left of the point 45.

The computer 34 then [carries out] performs , in the step of box 46, the calculation of the maximum elevated pressure produced ΔP_{MAX}.

This calculation can be [carried out] performed, for example, based on the formula:

with PRCH = pretension of the spring 16 = PRCMP x K, where PRCMP is the precompression of the spring 16 and K the rigidity of the spring 16,

LAI = distance travelled by the control rod in the lower portion 26 before impact, and

c3 = coefficient of hydraulic damping in order to model the damping in the lower portion 26.

In the event of a rebound, that is to say, when the spider 11 is no longer in contact with the upper end piece 7, the equation for movement of the control rod 10 in question is written as follows:

$$(M+\rho V)\frac{dv}{dt} = (M-\rho V)g - c3\,v$$

These two equations are integrated by the computer 34, for example, using the RUNGE-KUTTA method.

Therefore, the step 50 allows the kinematics of the control cluster 4 to be established during the mechanical damping of the shock by the spring 16. The speed profile established in this manner can be displayed, for example, by the [means] arrangement 40. This profile corresponds to the portion located to the right of the point 45 on the curve in Figure 7.

Based on the results of this step, the system 32 [carries out] performs, in the step 52, the calculation of a maximum vertical compression force F_{MAX}, to which the spring 16 is subjected during the mechanical damping.

This calculation can be [carried out] performed, for example, based on the following formula:

$$F_{MAX} = \max\{K(z-LAI) + PRCH\}$$

The system 32 then [carries out] performs, in the step of box 54, the calculation of an approximate maximum shearing stress τ_{MAX} in the spring 16:

$$\tau_{MAX} = \frac{8F_{MAX}DFN}{\pi DFR^3}$$

with DFN = DER-DFR and

DER = outside diameter of the spring 16,

DFR = diameter of the wire of the spring 16.

Subsequently, the system 32 can optionally [carry out] perform, based on the maximum stress τ_{MAX}, the calculation of maximum corrected stresses[:].

These stresses can be calculated by multiplying τ_{MAX} by different factors.

Thus, it is possible to calculate:

$$\tau_{MAX1} = \tau_{MAX} \text{ x } K_c \text{, and}$$
$$\tau_{MAX2} = \tau_{MAX} \text{ x } K,$$
$$\text{with Kc} = 1 + \frac{0.5}{C},$$
$$C = \frac{DFN}{DFR}, \text{ and}$$
$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

$\tau_{MAX1} = \tau_{MAX}$ x Kc, and

$\tau_{MAX2} = \tau_{MAX}$ x K,

with Kc = 1 + $\frac{0.5}{C}$,

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$$C = \frac{DFN}{DFR}, \text{ and}$$

$$K = \frac{4C-1}{4C-4} + \frac{0{,}615}{C}$$

The stress τ_{MAX1} corresponds to the shearing stress along the neutral axis FN (Figure 2) of the spring 16. The stress τ_{MAX2} corresponds to the stress along the axis F2 (Figure 2) of the spring 16 nearest the vertical [centre] center axis A of the spring 16 (see Figure 2).

At the end of this step illustrated by the box 56, the system 32 provides the various maximum shearing stresses calculated, for example, in the form of data stored in a file 57, which are transmitted by the input/output [means] arrangement 38.

Based on the data contained in the files 49 and 57, which have also been stored in the storage [means] arrangment 36, the computer 34 will verify that the maximum stresses calculated are indeed acceptable for the materials which respectively constitute the guide tube 24 and the helical spring 16.

This step has been schematically illustrated by the box 58 in Figure 5. During such a step, the system 32 will, for example, verify that the maximum shearing stresses calculated during the steps 54 and 56 are less than maximum values admissible by the material which constitutes the spring 16. This verification is [carried out] performed by a comparison of τ_{MAX}, τ_{MAX1} and τ_{MAX2} with a maximum value admissible by the material of the spring 16.

As far as the maximum circumferential stress $\sigma_{\theta MAX}$ is concerned, the verification can be [carried out] performed based on a formula of the type:

$$f\left(\sigma\theta_{MAX}\right) < \sigma_{admissible}$$

where $\sigma_{admissible}$ refers to the material which constitutes the lower portions 26 of the guide tubes 24.

The function f can be a function which takes into consideration other stresses to which the guide tubes 24 can be subjected. Such a stress can be a vertical compression σ_A, to which the guide tubes 24 are subjected during the contact of the springs 8 of the upper end piece 7 against the upper bearing plate of the core in order to counterbalance the hydrostatic thrust during operation.

Thus, the function f can be, for example, in the form of f $\sigma\theta_{MAX}$, $\sigma A) = \sigma\theta_{MAX} + \sigma A$.

It will be appreciated that this last step, illustrated by the box 58, can be [carried out] <u>performed</u> by separate software which generally [carries out] <u>performs</u> the validation of various design parameters of the assembly 1 based on results provided by various pieces of software each dedicated to taking into consideration specific operating conditions and which include the software which [carries out] <u>performs</u> the steps 42, 44, 46, 48, 50, 52, 54 and 56.

In general terms, the file 43 comprising the data 43 used by the method for the various calculations can comprise the data of Table 1 below.

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outside diameter of control rod 10	(m)	Nominal; maximum
inside diameter of upper portion 27	(m)	Nominal; maximum
inside diameter of lower portion 26	(m)	Nominal; maximum
total length of lower portion 26	(m)	
damping travel before impact	(m)	
minimum thickness of wall of lower portion 26	(m)	
maximum roughness of rod 10/tube 24	(m)	
diameter of aperture 29	(m)	
length of aperture 29	(m)	
roughness of aperture 29	(m)	
moving mass M	(kg)	
volumetric mass of liquid	(kg/m^3)	
kinematic viscosity of liquid	(m^2/s)	
c1	(/m)	
c2	(m/s^2)	
Young's modulus of guide tube 24	(Pa)	
Poisson's ratio of guide tube 24		
spring precompression 16	(m)	
preloading of spring 16	(N)	
length of spring 16 with contiguous turns	(m)	
outside diameter of spring 16	(m)	
diameter of wire of spring 16	(m)	
compression when upper head 12 is in contact with upper end piece 7.	(m)	
END		

Table 1

Similarly, the file 49 comprising the results from step 48 [can] an comprise the data of Table 2 below.

ΔP_{MAX}: maximum elevated pressure in lower portion 26	(Pa)
Z_{MAX}: corresponding penetration in lower portion 26	(m)
$\sigma_{\theta MAX}$: maximum stress in lower portion 26	(Pa)
fmax: maximum force on lower end piece 6	(N)
tdur: duration of fall in lower portion 26 before impact	(s)
vfin: speed of impact of assembly 4 on upper end piece 7	(m/s)

Table 2

The file 57 comprising the results of step 56 can itself contain the data of Table 3 below.

F_{MAX}: maximum compression force on spring 16	(N)
h_{MAX}: maximum deflection of spring 16	(m)
τ_{MAX} : approximate maximum stress in spring	(Pa)
τ_{MAX1} : approximate maximum stress corrected by Kc	(Pa)
τ_{MAX2} : approximate maximum stress corrected by K (Wahl coefficient)	Pa)

Table 3

It has been possible to verify by experiment that the maximum elevated pressures and the maximum stresses obtained by means of steps 42, 44, 46 and 48 were reliable. In this manner, the first corresponding part of the method allows reliable guide tubes 24 to be designed. Furthermore, this first part calculates only a single stress which appears to be the pertinent stress for the conditions being considered. Consequently, this first part of the method allows the security margins to be limited during design, and therefore assemblies which are relatively light and economical to be designed.

The second part of the method, which corresponds to steps 50, 52 54 and 56, also allows maximum stresses to be reliably calculated, as confirmed by experiment.

Thus, the second part of the method allows a reliable design to be arrived at by calculation for the spider springs 16, which design is found to be advantageous in comparison with the method of tests alone which is currently imposed by provisions. It will be appreciated that the second part of the method calculates only the small number of stresses, and in particular those on the axis F2 of the spring 16 nearest the [centre] center axis A of the spring, which are found to be pertinent to the conditions envisaged. In this manner,

the second part of the method allows the design margins to be reduced.

In more general terms, the steps 42, 44, 46 and 48, on the one hand, and 50, 52, 54 and 56, on the other, can be [carried out] performed by separate pieces of software.

In order to increase the reliability of the calculation, for [carrying out] performing the first part of the method it is possible to use, as the passage gap J, the nominal value of the gap, or this nominal value corrected by the manufacturing tolerance, or a value resulting from statistical studies of the distribution of passage gaps J obtained in constructed assemblies.

In a variant, it is possible to use a gap value J which is greater for steps 42 and 44 and a smaller gap value J for steps 46 and 48. This allows a high stress value $\sigma_{\theta MAX}$ to be calculated because the speed reached during the fall of the rod 10 in question is high and the volume available in the lower portion 26 for the liquid during damping is small. However, this high stress value is not unrealistic and therefore does not lead to unjustified design margins, as illustrated by the following example.

According to a specific variant, the upper value can be a maximum value for gap J which is verified with a given probability, for example, 95%, in constructed assemblies, and the lower value can be a minimum value obtained with the same probability. This variant allows an approximation of the situation where a single pair comprising a guide tube/control rod has minimum gap J, where the maximum stress $\sigma_{\theta MAX}$ would be reached, and where all the other pairs comprising a guide tube/control rod have the maximum passage gap J, which would be the most extreme case.

ABSTRACT

A method for designing a nuclear fuel assembly, including the steps of establishing a progression of a speed of the control cluster after the impact of the support against the upper end piece, establishing, based on the speed established in step a), a maximum longitudinal load for compression of the spring, and establishing, based on the maximum longitudinal load for compression, at least a maximum shearing stress in the spring.

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METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT

FIELD OF INVENTION

The present invention relates to a method for designing a nuclear fuel assembly which is intended to be positioned in a nuclear reactor, the assembly comprising a plurality of guide tubes, and a control cluster which itself comprises a plurality of control rods which are received in the guide tubes and a support for control rods, the assembly comprising a helical spring for damping the impact of the support against an upper end piece of the assembly in the event of the control cluster falling during a shutdown of the nuclear reactor.

BACKGROUND OF THE INVENTION

It will be appreciated that nuclear fuel assemblies must be dependable in order to allow reliable operation of nuclear reactors. Thus, design and construction provisions for such assemblies have been drawn up.

These provisions impose a general framework and minimum criteria which the assembly constructors must take into consideration.

As far as the helical damping spring is concerned, the design provisions require verification by means of tests that the integrity of the spring has not been affected during the impact brought about in the event of a shutdown of the reactor.

Although the criterion imposed by the design provisions allows assemblies to be designed with satisfactory reliability, it would be desirable to limit the safety

margins during design in order to reduce the mass and the cost of the assemblies constructed.

SUMMARY OF THE INVENTION

An objective of the invention is to overcome this problem by providing a method which allows reliable nuclear fuel assemblies to be designed, while limiting the design margins.

To this end, the invention relates to a method for designing a nuclear fuel assembly which is intended to be positioned in a nuclear reactor, the assembly comprising a plurality of guide tubes and a control cluster which itself comprises a plurality of control rods which are received in the guide tubes and a support for control rods, the assembly comprising a helical spring for damping the impact of the support against an upper end piece of the assembly in the event of the control cluster falling during a shutdown of the nuclear reactor, wherein the method comprises the following steps:

a) establishing a progression of a speed of the control cluster after the impact of the support against the upper end piece,

b) establishing, based on the speed established in step a), a maximum longitudinal load for compression of the spring, and

c) establishing, based on the maximum longitudinal load for compression, at least a maximum shearing stress in the spring.

According to specific embodiments, the method can comprise one or more of the following features, taken in isolation or according to all technically feasible combinations:

- a maximum shearing stress is a shearing stress along the neutral axis of the spring,

- a maximum shearing stress is a shearing stress along the axis of the spring nearest the longitudinal centre axis thereof,

- the method further comprises a step for verifying, using a maximum shearing stress established in step c), that a maximum stress admissible by the spring has not been exceeded.

The invention further relates to a system for designing a nuclear fuel assembly, wherein it comprises an arrangement for performing the steps of a method as defined above.

According to a variant of the invention, the system comprises a computer and storage arrangement, in which at least a program comprising instructions for performing steps of the method for designing a nuclear fuel assembly is stored.

The invention further relates to a computer program comprising instructions for performing the steps of a method as defined above.

The invention also relates to a medium which can be used in a computer and on which a program as defined above is recorded.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from a reading of the description below which is given purely by way of example with reference to the appended drawings.

Figure 1 is a schematic, perspective cutaway view of a nuclear fuel assembly which is designed by a method according to the present invention.

Figure 2 is a schematic, partially sectioned side view drawn to an enlarged scale of the structure of the spider of the assembly of Figure 1.

Figure 3 is a partial schematic side view of the assembly of Figure 1, illustrating more particularly a pair comprising a guide tube/control rod.

Figure 4 is a block diagram illustrating the system for designing the assembly of Figure 1.

Figure 5 is a flow chart illustrating successive steps of the design method carried out by the system of Figure 4.

Figure 6 is a progression curve of the falling speed of a control rod before it is introduced in the lower portion of the corresponding guide tube, this progression being calculated by the system of Figure 4.

Figure 7 is a progression curve of the falling speed of the same control rod in the lower portion of the corresponding guide tube, this progression being calculated by the system of Figure 4.

DETAILED DESCRIPTION

Figure 1 illustrates a nuclear fuel assembly 1 which mainly comprises a square-based lattice 2 for nuclear fuel rods 3 and a control cluster 4.

The assembly 1 comprises grids 5 for maintaining the rods 3, the grids 5 distributed over the height of the rods 3. A lower end piece 6 is arranged under the lower ends of the rods 3 and an upper end piece 7 above the upper ends of the rods 3. The upper end piece 7 is provided with springs 8 for pressing against the upper bearing plate of the reactor core, in which the assembly 1 is intended to be placed.

The control cluster 4 comprises a plurality of control rods 10, for example, 24. Conventionally, the control rods 10 comprise a material which absorbs neutrons.

The rods 3 and 10 extend in parallel with a vertical longitudinal direction L.

The rods 10 are carried at the upper ends thereof by a support 11 which is generally referred to as a spider.

As illustrated more particularly in Figure 2, the spider 11 comprises a vertical central upper head 12 and a series of arms or vanes 13 which extend radially outwards from the lower end of the upper head 12 as far as the radially outer ends 14 thereof. Each control rod 10 is connected to an arm 13 at the upper end thereof.

The upper head 12 of the spider 11 has a central blind hole 15 which opens towards the bottom and in which a damping helical spring 16 is received. The spring 16 extends vertically along a center axis A. A tightening screw 17 extends substantially over the entire height of the hole 15 and is screwed into the wall 18 delimiting the upper portion of the hole 15.

The lower portion of the screw 17 extends through the base of a retaining ring 20 which rests on the lower end of the spring 16. The head 21 of the screw 17 rests, at the top, against the base of the retaining ring 20 in order to press the spring 16 against the wall 18 of the upper head 12.

As illustrated in Figure 3 for a control rod 10, each control rod 10 is received in a respective guide tube 24 which is arranged in the lattice 2 of fuel rods 3. In this manner, 24 pairs comprising a guide tube/control rod are formed. Since each of these pairs has a similar structure, only one will be described below.

The guide tube 24 extends from the lower end piece 6 as far as the upper end piece 7. The guide tube 24 comprises a lower portion 26 of reduced inside diameter and an upper portion 27. The lower portion 26 is connected to the lower end piece 6 by a collared screw 28, through which a vertical through-hole 29 extends.

The lower portion 26 of the guide tube 24 surrounds the control rod 10 with a radial passage gap J.

The upper portion 27 is fixed to the upper end piece 7 and opens at the outside of the assembly 1.

Lateral apertures 30, only one of which can be seen in Figure 4, are provided in the upper portion 27 near the lower portion 26.

When the assembly 1 is placed in a nuclear reactor, the cooling liquid of the reactor fills the interior of the guide tube 24.

Conventionally, the control cluster 4 can be moved vertically relative to the remainder of the assembly 1 in order to allow adjustment of the reactivity during normal operation of the reactor, and therefore variations in power from zero power up to maximum output depending on the vertical introduction of the control rods 10 in the lattice 2 of rods 3. The vertical displacement of the control cluster 24 is conventionally carried out by a drive rod which is connected to the upper end of the upper head 12.

When the reactor is shut down, the drive rod and the assembly 4 fall due to gravity.

At the start of this falling movement, the control rods 10 are guided only by the upper portions 27 of the guide tubes 24 and have not yet reached the lower portions 26.

Once the falling action has ended, the lower ends of the control rods 10 are introduced in the lower portions 26. The cooling fluid contained in the portions 26 is then violently forced, on the one hand, upwards thereby and, on the other hand, downwards through the apertures 29 of the collared screws 28.

Each lower portion 26 therefore behaves in the manner of a hydraulic damper braking the falling movement of the corresponding control rod 10, and therefore of the assembly 4.

This braking phase ends at the end of the travel path with the impact of the spider 11 against the upper end piece 7 of the assembly 1.

This impact is carried out by a retaining ring 20. During this impact, the spring 16 is compressed vertically in order to absorb the shock.

According to the invention, the assembly 1 has been designed in order to take into consideration the specific stresses brought about in the assembly by the fall of the control cluster 4 during such a shutdown of the reactor.

In this manner, in order to design the assembly 1, in particular a data-processing system 32 has been used, as illustrated schematically in Figure 4.

This system 32 comprises, for example, a computer or data processing unit 34 comprising one or more processors, a storage arrangement 36, input/output arrangement 38, and optionally display arrangement 40.

Instructions which can be performed by the computer 34 are stored in the form of one or more programs in the storage arrangement 36.

These instructions are, for example, instructions in FORTRAN programming code.

These various instructions, when they are performed by the computer 34, allow the method illustrated by the flow chart of Figure 5 to be performed.

In a first step illustrated by the box 42 of this Figure, the computer 34 calculates, based on data 43, the

development of the falling speed of a control rod 10 in the upper portion 27 of the corresponding guide tube 24 in the event of a shutdown of the reactor.

This calculation can be performed assuming, for example, that the control rod 10 is first subjected to constant loads:

- gravitational force: fg = Mg,
- Archimedes' thrust: fa = -p gV,
- pressure difference in the core: fc, and
- mechanical friction: fm,

where M and V are the mass and the volume, respectively, of the assembly 4 and the drive rod thereof.

The control rod 10 is also subjected to loads as a function of the speed or position thereof, for example, hydraulic friction which can be obtained from: fh = -c1 (M + pV) v^2, with v = speed of the assembly 4 and therefore of the rod 10 in question.

Thus, the equation of the movement of the rod in the upper portion 27 of the guide tube 24 is as follows:

$$\left(M+\rho V\right)\frac{dv}{dt}=\Sigma f$$

This gives:

$$\frac{dv}{dt}=c2-c1\,v^2$$

with c1 = hydraulic friction in the guide tube and

$$c2=\frac{fg+fa+fc+fm}{M+\rho V}.$$

C1 and c2 are, for example, experimental data measured during drop tests of the control cluster 4. These data are,

with the other data necessary for the calculation, such as the mass and the volume of the assembly 4 and the drive rod thereof, introduced, for example, in the form of a file 43 by way of the input/output arrangement 38.

The computer 34 resolves the equation of the movement of the control rod 10, for example, using the NEWTON method.

Thus, the progression of the speed of the control rod 10 in the upper portion 27 is known as a function of time. The profile established in this manner can be displayed in the form of a curve by the display arrangement 40. This curve is illustrated by Figure 6.

In this manner, at the end of the step illustrated by the box 42, the speed of the control rod 10 is known at the point of entry to the lower damping portion 26 of the guide tube 24.

Based on the results of the step of box 42, the computer 34 calculates the progression of the speed of the control rod 10 during its fall in the lower damping portion 26.

This step is schematically illustrated by the box 44.

This step can be carried out using the following equation:

$$-\frac{dv}{dt} = c2 - \left(c1 + \frac{SCA\mathrm{x}NCA\Delta P}{M+\rho V \quad v^2} \right) v^2$$

with $$c2 = \frac{fg+fa}{M+\rho V} = \frac{M-\rho V}{M+\rho V} g$$

SCA = cross-section of the rod 10 and

NCA number of rods 10 in the assembly 4.

Therefore, the hypothesis that f_c and f_m are negligible is applied here.

The difference ΔP represents the elevated pressure produced in the cooling liquid contained in the guide tube 24, that is to say, the pressure thereof between the lower end of the rod 10 and the pressure present in the upper portion 27 of the guide tube 24.

ΔP can be established by the following formula:

$$\Delta P = \frac{1}{2} pQ^2 v^2 (EXPA + CONTRA + FECR x CISA xz)$$

where $EXPA = \left(\frac{SCA}{SACM} \left(1 \frac{SACM}{SACTG} \right) \right)^2$

with SM = cross-section of the lower portion 26,

SACM = SM - SCA = cross-section of the annular space between the rod 10 and the lower portion 26,

SACTG = STG - SCA, where STG is the cross-section of the upper portion 27 of the guide tube 24,

$$CONTRA = 0.4 \left(1 \frac{SACM}{SM} \right) \left(\frac{SCA}{SACM} \right)^2,$$

FECR = coefficient of loss of load owing to friction in the lower portion 26,

$$CISA = \left(\frac{SCA}{SM} \right)^2 \frac{1}{DM},$$

DM = mean diameter of the guide tube 24 in the upper portion 27,

z = height of the rod 10 introduced in the lower portion 26 of the guide tube 24, and

Q = fraction of liquid, flowing upwards out of the lower portion 26.

The resolution of the equations governing the movement of the rod 10 after entry into the lower portion 26 is carried

out by the computer 34, for example, using the RUNGE-KUTTA method.

Thus, at the end of the step 44, the progression of the speed of the control rod 10 in the lower portion 26 of the guide tube 24 is known before the impact of the spider 11 on the upper end piece 7.

The speed profile established in this manner can be displayed, for example, by the arrangement 40, as illustrated in Figure 7. On the curve in Figure 7, the speed profile established during step 44 is the portion located to the left of the point 45.

The computer 34 then performs, in the step of box 46, the calculation of the maximum elevated pressure produced ΔP_{MAX}.

This calculation can be performed, for example, based on the formula:

$$\Delta P = \frac{1}{2}\rho Q^2 v^2 (EXPA + CONTRA + FECRxCISAxz).$$

The computer 34 performs, in the step of box 48, the calculation of a circumferential stress and maximum normal $\sigma_{\theta MAX}$, to which the lower portion 26 of the guide tube 24 is subjected owing to the maximum elevated pressure ΔP_{MAX}.

This stress can be calculated based on the formula:

$$\sigma_{\theta MAX} = \frac{1}{2}\Delta P_{MAX}\left(\frac{DPM}{EMP} + 1\right),$$

where DPM = inside diameter of the lower portion 26 and EMP = minimum thickness of the wall of the lower portion 26.

The system 32 can then provide, owing to the input/output means 38, a first result in the form of a file 49 containing the value $\sigma_{\theta MAX}$ established, and optionally the maximum elevated pressure ΔP_{MAX} established.

Next, the system 32 performs the calculation of the progression of the speed of the control rod 10 after it comes into contact with the spider 11 and the upper end piece 7. This calculation step is illustrated by the box 50 in figure 5.

This calculation can be performed, for example, using the following equation when the ring 20, and therefore the spider 11, is in contact with the upper end piece 7:

$$\left(M+\rho V\right)\frac{dv}{dt}=\left(M-\rho V\right)g-PRCH-K(z-LAI)-c3\,v$$

with PRCH = pretension of the spring 16 = PRCMP x K, where PRCMP is the precompression of the spring 16 and K the rigidity of the spring 16,

LAI = distance travelled by the control rod in the lower portion 26 before impact, and

c3 = coefficient of hydraulic damping in order to model the damping in the lower portion 26.

In the event of a rebound, that is to say, when the spider 11 is no longer in contact with the upper end piece 7, the equation for movement of the control rod 10 in question is written as follows:

$$\left(M+\rho V\right)\frac{dv}{dt}=\left(M-\rho V\right)g-c3\,v$$

These two equations are integrated by the computer 34, for example, using the RUNGE-KUTTA method.

Therefore, the step 50 allows the kinematics of the control cluster 4 to be established during the mechanical damping of the shock by the spring 16. The speed profile established in this manner can be displayed, for example, by the arrangement 40. This profile corresponds to the portion

located to the right of the point 45 on the curve in Figure 7.

Based on the results of this step, the system 32 performs, in the step 52, the calculation of a maximum vertical compression force F_{MAX}, to which the spring 16 is subjected during the mechanical damping.

This calculation can be performed, for example, based on the following formula:

$$F_{MAX} = \max\ \{K(z-LAI) + PRCH\}$$

The system 32 then performs, in the step of box 54, the calculation of an approximate maximum shearing stress τ_{MAX} in the spring 16:

$$\tau_{MAX} = \frac{8F_{MAX}DFN}{\pi DFR^3}$$

with DFN = DER-DFR and

DER = outside diameter of the spring 16,

DFR = diameter of the wire of the spring 16.

Subsequently, the system 32 can optionally perform, based on the maximum stress τ_{MAX}, the calculation of maximum corrected stresses.

These stresses can be calculated by multiplying τ_{MAX} by different factors.

Thus, it is possible to calculate:

$$\tau_{MAX1} = \tau_{MAX} \text{ x } K_c, \text{ and}$$
$$\tau_{MAX2} = \tau_{MAX} \text{ x } K,$$
$$\text{with Kc} = 1 + \frac{0.5}{C},$$
$$C = \frac{DFN}{DFR}, \text{ and}$$
$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

The stress τ_{MAX1} corresponds to the shearing stress along the neutral axis FN (Figure 2) of the spring 16. The stress τ_{MAX2} corresponds to the stress along the axis F2 (Figure 2) of the spring 16 nearest the vertical center axis A of the spring 16 (see Figure 2).

At the end of this step illustrated by the box 56, the system 32 provides the various maximum shearing stresses calculated, for example, in the form of data stored in a file 57, which are transmitted by the input/output arrangement 38.

Based on the data contained in the files 49 and 57, which have also been stored in the storage arrangment 36, the computer 34 will verify that the maximum stresses calculated are indeed acceptable for the materials which respectively constitute the guide tube 24 and the helical spring 16.

This step has been schematically illustrated by the box 58 in Figure 5. During such a step, the system 32 will, for example, verify that the maximum shearing stresses calculated during the steps 54 and 56 are less than maximum values admissible by the material which constitutes the spring 16. This verification is performed by a comparison of τ_{MAX}, τ_{MAX1} and τ_{MAX2} with a maximum value admissible by the material of the spring 16.

As far as the maximum circumferential stress $\sigma_{\theta MAX}$ is concerned, the verification can be performed based on a formula of the type:

$$f\left(\sigma\theta_{MAX}\right) < \sigma_{admissible}$$

where $\sigma_{admissible}$ refers to the material which constitutes the lower portions 26 of the guide tubes 24.

The function f can be a function which takes into consideration other stresses to which the guide tubes 24 can be subjected. Such a stress can be a vertical compression stress σ_A, to which the guide tubes 24 are subjected during the contact of the springs 8 of the upper end piece 7 against the upper bearing plate of the core in order to counterbalance the hydrostatic thrust during operation.

Thus, the function f can be, for example, in the form of f $(\sigma\theta_{MAX}, \sigma A) = \sigma\theta_{MAX} + \sigma A$.

It will be appreciated that this last step, illustrated by the box 58, can be performed by separate software which generally performs the validation of various design parameters of the assembly 1 based on results provided by various pieces of software each dedicated to taking into consideration specific operating conditions and which include the software which performs the steps 42, 44, 46, 48, 50, 52, 54 and 56.

In general terms, the file 43 comprising the data 43 used by the method for the various calculations can comprise the data of Table 1 below.

outside diameter of control rod 10	(m)	Nominal; maximum
inside diameter of upper portion 27	(m)	Nominal; maximum
inside diameter of lower portion 26	(m)	Nominal; maximum
total length of lower portion 26	(m)	
damping travel before impact	(m)	
minimum thickness of wall of lower portion 26	(m)	
maximum roughness of rod 10/tube 24	(m)	
diameter of aperture 29	(m)	
length of aperture 29	(m)	
roughness of aperture 29	(m)	
moving mass M	(kg)	
volumetric mass of liquid	(kg/m^3)	
kinematic viscosity of liquid	(m^2/s)	
c1	(/m)	
c2	(m/s^2)	
Young's modulus of guide tube 24	(Pa)	
Poisson's ratio of guide tube 24		
spring precompression 16	(m)	
preloading of spring 16	(N)	
length of spring 16 with contiguous turns	(m)	
outside diameter of spring 16	(m)	
diameter of wire of spring 16	(m)	
compression when upper head 12 is in contact with upper end piece 7.	(m)	
END		

Table 1

Similarly, the file 49 comprising the results from step 48 an comprise the data of Table 2 below.

ΔP_{MAX}: maximum elevated pressure in lower portion 26	(Pa)
Z_{MAX}: corresponding penetration in lower portion 26	(m)
$\sigma_{\theta MAX}$: maximum stress in lower portion 26	(Pa)
fmax: maximum force on lower end piece 6	(N)
tdur: duration of fall in lower portion 26 before impact	(s)
vfin: speed of impact of assembly 4 on upper end piece 7	(m/s)

Table 2

The file 57 comprising the results of step 56 can itself contain the data of Table 3 below.

F_{MAX}: maximum compression force on spring 16	(N)
h_{MAX}: maximum deflection of spring 16	(m)
τ_{MAX}: approximate maximum stress in spring	(Pa)
τ_{MAX1}: approximate maximum stress corrected by Kc	(Pa)
τ_{MAX2}: approximate maximum stress corrected by K (Wahl coefficient)	(Pa)

Table 3

It has been possible to verify by experiment that the maximum elevated pressures and the maximum stresses obtained by means of steps 42, 44, 46 and 48 were reliable. In this manner, the first corresponding part of the method allows reliable guide tubes 24 to be designed. Furthermore, this first part calculates only a single stress which appears to be the pertinent stress for the conditions being considered. Consequently, this first part of the method allows the security margins to be limited during design, and therefore assemblies which are relatively light and economical to be designed.

The second part of the method, which corresponds to steps 50,52, 54 and 56, also allows maximum stresses to be reliably calculated, as confirmed by experiment.

Thus, the second part of the method allows a reliable design to be arrived at by calculation for the spider springs 16, which design is found to be advantageous in comparison with the method of tests alone which is currently imposed by provisions. It will be appreciated that the second part of the method calculates only the small number of stresses, and in particular those on the axis F2 of the spring 16 nearest the center axis A of the spring, which are found to be pertinent to the conditions envisaged. In this manner, the second part of the method allows the design margins to be reduced.

In more general terms, the steps 42, 44, 46 and 48, on the one hand, and 50, 52, 54 and 56, on the other, can be performed by separate pieces of software.

In order to increase the reliability of the calculation, for performing the first part of the method it is possible to use, as the passage gap J, the nominal value of the gap, or this nominal value corrected by the manufacturing tolerance, or a value resulting from statistical studies of the distribution of passage gaps J obtained in constructed assemblies.

In a variant, it is possible to use a gap value J which is greater for steps 42 and 44 and a smaller gap value J for steps 46 and 48. This allows a high stress value $\sigma_{\theta MAX}$ to be calculated because the speed reached during the fall of the rod 10 in question is high and the volume available in the lower portion 26 for the liquid during damping is small. However, this high stress value is not unrealistic and

therefore does not lead to unjustified design margins, as illustrated by the following example.

According to a specific variant, the upper value can be a maximum value for gap J which is verified with a given probability, for example, 95%, in constructed assemblies, and the lower value can be a minimum value obtained with the same probability. This variant allows an approximation of the situation where a single pair comprising a guide tube/control rod has minimum gap J, where the maximum stress $\sigma_{\theta MAX}$ would be reached, and where all the other pairs comprising a guide tube/control rod have the maximum passage gap J, which would be the most extreme case.

In some variants, the first part of the method could also take into consideration forms of the lower damping portion 26 which are different from those described previously. In this manner, these lower damping portions could have a plurality of successive portions of reduced diameter, optionally separated by portions of increased diameter, generally referred to as cavities. In some variants, the first part of the method is performed with collared screws 28 which are not perforated by holes 29.

In still more general terms, the first part and the second part of the design method described can be used independently of each other. In this manner, it is possible to perform the second part relating to the design of the spring 16 without referring to the calculation of the elevated pressure ΔP and the stress $\sigma_{\theta MAX}$.

ABSTRACT

A method for designing a nuclear fuel assembly, including the steps of establishing a progression of a speed of the control cluster after the impact of the support against the upper end piece, establishing, based on the speed established in step a), a maximum longitudinal load for compression of the spring, and establishing, based on the maximum longitudinal load for compression, at least a maximum shearing stress in the spring.

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

INFORMATION DISCLOSURE STATEMENT		Docket Number 12928/10019	
Application Number To Be Assigned (PCT International Application No.: PCT/FR03/00556	Filing Date Herewith (International Filing Date: 02.19.03)	Examiner To Be Assigned	Art Unit To Be Assigned
Invention Title METHOD FOR DESIGNING THE SPIDER SPRING OF A CONTROL CLUSTER OF A NUCLEAR FUEL ASSEMBLY, A CORRESPONDING SYSTEM, COMPUTER PROGRAM AND PRODUCT		Inventor(s) Catherine CALLENS et al.	

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

1. In accordance with the duty of disclosure under 37 C.F.R. § 1.56 and in conformance with the procedures of 37 C.F.R. §§ 1.97 and 1.98 and M.P.E.P. § 609, attorneys for Applicants hereby bring the following references (cited in the specification of the above-identified application) to the attention of the Examiner. The references are listed on the attached modified PTO Form No. 1449. It is respectfully requested that the information be expressly considered during the prosecution of this application, and that the references be made of record therein and appear among the "References Cited" on any patent to issue therefrom.

2. A copy of each patent, publication or other information listed on the modified PTO form 1449 is not enclosed since the patent application was filed after June 30, 2003.

Dated: 9/1/04

By: John M. Vereb
John M. Vereb (Reg. No. 48,912)

KENYON & KENYON
One Broadway
New York, N.Y. 10004
(212) 425-7200 (telephone)
(212) 425-5288 (facsimile)

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	APPLICANT Catherine CALLENS et al.	
	FILING DATE Herewith	GROUP To be assigned

U. S. PATENT DOCUMENTS

EXAMINER INITIAL	PATENT NUMBER	PATENT DATE	NAME	CLASS	SUBCLASS	FILING DATE
	4,826,648*	May 2, 1989	Savary			
	5,076,995*	December 31, 1991	Canat			

* Cited in International Search Report, copy not enclosed, provided by International Searching Authority.

FOREIGN PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION	
						YES	NO

* Cited in International Search Report, copy not enclosed, provided by International Searching Authority.

OTHER DOCUMENTS

EXAMINER INITIAL		AUTHOR, TITLE, DATE, PERTINENT PAGES, ETC.

* Cited in International Search Report, copy not enclosed, provided by International Searching Authority.

EXAMINER	DATE CONSIDERED
EXAMINER: Initial if citation considered, whether or not citation is in conformance with M.P.E.P. 609; draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.	

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